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Influence of Sugar Cane Mechanical Harvest on Clear Juice Quality at Elguneid Sugar Factory

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ABSTRACT

This study aimed to investigate the influence of mechanical harvest on juice clarification in Elguneid sugar factory. Elguneid factory was designed to treat a hand cut cane more than a mechanical cut cane. So, the clarification system was tuned to meet this purpose. Color, turbidity, reducing sugar, sugar content, purity, pH, brix, temperature and phosphate content were determined. The results showed: the color has increased from 3910 to 13921 ICUMSA, turbidity from 3242 to 8496 and reducing sugar increased to 0.928%. Sucrose content decreased from 14.39 to 11.69% and purity from 88 to 83%. The results of Pol% and Purity% were taken at the beginning of crushing season, where the mechanical harvest was higher than hand cut. A comparative study between hand cut and mechanical harvest was made at the middle of the crushing season. The optimum brix in the clarifiers matched the turbidity decreased at brix 12%, 13% respectively. Also from the tests carried out it was shown that the flocculant and phosphoric acid, which were used by the factory personnel was lower than the standard values, phosphoric acid was 183ppm and the polymer was 1,6ppm. These low values affected the precipitation process. There is a relationship between the amount of mud and type of harvest. It was noticed that there is a relationship between sugar yield and type of harvest.

Keyword: Sugar Cane, Mechanical Harvest, Juice Quality, Elguneid.

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INTRODUCTION

Sugar (sucrose), is a carbohydrate that occurs naturally in every fruit and vegetable and in greatest quantities in sugar beets and sugar cane from which it is separated for commercial use (Matush, 1988).

Mechanical harvesting of cane is generally carried out by chopper harvesters. These are machines which cut the cane, chopping it into pieces and discharging it into truck or trailer circulate in the field, holding tones of cane, and then transfer their load to a road (or rail) vehicle which runs the length of the field and transporting its load to the factory (Hugot, 1972).

Millions of dollars a year are lost in the sugar industry because of the degradation of sugars in process (Gillian and Margaret, 1998).

Every sugar technologist knows that, without good clarification of sugar cane juice, the production of good quality raw sugar is impossible (Baikow, 1982).

A clarification process may be defined as one in which the expressed juice from the mill is subjected to treatment by the application of milk of lime, phosphates and the addition of heat to settle impurities and mud. The clear supernatant juice is removed by decantation (Honig, 1970).

The purpose of clarification is the precipitation and removal of all possible non sugars, organic and inorganic, and the preservation of the maximum sucrose and reducing sugars possible in the clarified juice. Poor clarification of cane juices complicates the entire process of sugar manufacture.

During the process of clarification, the suspended matter and heavy particles coagulated by lime and heat settle on the surface of clarifier trays in the form of sludge, or ‘mud’ as it is called. This mud is removed from the clarifier trays into the mud thickening compartment with long arms to which squeegees are attached. From the thickening compartment of the clarifier, the mud is lifted, by means of suction diaphragm pumps, into the mud box from which it flows by gravity to the mud filter station. A small amount of milk of lime can be added to the mud with phosphoric acid, making it more granular and improving filtration (Baikow, 1982). The Objectives of this work were to study the mud increase and its influence on sedimentation rate, quality parameters of clear juice at high mechanical harvesting rate in comparison with low rate of mechanical harvest, and the influence of brix content on clarifier performance.

MATERIALS AND METHODS

Materials

Clear juice samples were collected from Elguneid sugar factory during the crop season 2009 – 2010.

Preparation of cane juice

Mixed juice was extracted from sugar cane by milling and the pH was about 5.0 - 5.4. Then, the extracted juice was treated by chemicals (phosphoric acid and lime) immediately in treatment tank, then the treated juice was pumped into the flash tank and then to clarificatier (where separan was added). Finally the analyses were carried out on the obtained juice.

Methods of Analysis

Clear Juice

pH Measurement

Electrometric method employing pH-meter with glass electrode assembly was used for pH measurement.

Brix Determination

The refractometer was adjusted to zero with distilled water. A drop of juice was placed on the refractometer. Then the brix was read.

Determination of Pol %

The polarization of juice was measured by a polarimeter according to the method described by Horne's dry lead (South African Sugar Technologist's Association (1985)). Approximately 150 ml of the sample was taken in a bottle provided with stopper. Sufficient lead sub acetate powder (1.5g) was added for clarification, shacked vigorously to disperse the lead sub-acetate completely and then allowed to stand and filtered through a fluted filter paper held in the funnel. Some of the filtrate was used for rinse the Pol tube and filled completely .Then the polarization (saccharimeter reading) was read. The Pol % obtained from Schmitz's table by using the Brix of the sample and saccharimeter reading.

Determination of Purity %

The Purity of juice was calculated according to the following formula: The Purity

$$\% = \left(\frac{Pol}{Brix}\right)\cdot 100$$

Determination of Reducing Sugar

Eynon and lane method (South African Sugar Technologist's Association (1985)) was used for determination of reducing sugars, in which 20 ml of screened sample was poured into clean volumetric flask (100ml); 10 ml of EDTA (4%) was added and made up to the mark with distilled water. Burette (50ml) was rinsed by the diluted juice before filled and adjusted to zero. 5ml of Fehling solution A and 5ml of Fehling solution B was pipette into the boiling flask. 15ml of the diluted juice from the burette was added; the flask was placed on a fast hot plate, and then allowed to boil for 2 minutes. Three four drops of methylene blue were added and the addition of the solution from the burette was continued until the indicator was completely decolorized. The percentage of reducing sugar was found referring to table of mg reducing sugar required to reduce 10ml Fehling solution.

Determination of Color and Turbidity:

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The color and turbidity of the juice were determined according to ICUMSA method (South African Sugar Technologist's Association (1985)), by using spectrophotometer. Absorbance was measured at 420nm color. This calculated as follows:

ICUMSA 420 color $= (\frac{As}{bc}).1000$

Where:

As = absorbance at 420 nm

b = cell length (mm)

c = concentration of total solid (g/ml)

The Turbidity of the unfiltered juice solution (s1) was calculated as follows

Turbidity = ((absorbency index of the unfiltered sample)*100) _ ICUMSA 420 color

Absorbency index of the unfiltered sample = $(\frac{Aus}{bc}).10$

Aus = absorbance of the unfiltered sample at 420

b = cell length (mm)

c = concentration of total solid (g/ml)

Determination of Optimum Brix

Three cylinders were made up to 1000ml by the limed juice. These cylinders were treated by (3ml) separan solution, and then allowed to settle for 2 - 3 hours. The clear juice obtained was analyzed for pH, brix, pol%, purity, color and turbidity.

Phosphate Determination

5 drops from ammonium solution were added to 100 ml juice, 1 ml acidic acid plus 1g from Ammonia chloride were added. Titration was made with the standard uranium solution using powered potassium hexacyanoferrate as an indicator.

RESULTS AND DISCUSSION

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Optimum Brix and Mud Volume:

The brix considered as the percentage by weight of dissolved solids in a solution.

Table (1), shows the brix values juice against the mud level obtained.

, this is %– 18 The mixed juice brix in Elguneid sugar factory ranges between 15 considered as an indication of low quantity of imbibition water added during the milling . This %process. According to Karmarkar (1999) mixed juice brix lies between 12 – 15 high brix level of mixed juice used in Elguneid sugar factory causes a problem, because the impurities do not settle easily in the clarifier. So it is recommended to keep the brix in , which matches the mud volume of 185ml as shown in Table (1).%the clarifier at 12

Mud level is an indication of impurities from the original juice. These impurities due to mechanical harvest cause different problems in sugar processing at various stages. The clarity of the treated juice depends on the quality of mud coming with sugar cane. Extra mud level will lead to extra sugar losses.

Table (1): Relationship between Mud Level and Brix Values.

Time (min)	Mud level (ml) at Bix 14%	Mud level (ml) at Brix 13%	Mud level (ml) at Brix 12%
10	165	190	285
20	145	180	250
30	135	155	225
40	130	150	220
50	128	145	210
60	120	140	200
70	120	135	200
80	120	135	190
90	119	130	190
100	119	130	185
110	119	130	185
120	119	130	185

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Table (2) shows the values of quality parameters for clear juice at different brix 14, 13 and 12%. The pH, Pol% and color have no variations in values. The turbidity value at 12% constitutes 5315, which is low in comparison with other turbidity values.

The purity% at brix 12% level was higher in comparison with samples at brix 14%, 13%. Therefore it is recommended to maintain the brix% in the clarifier at 12% to obtain a clear juice with a good quality. There is a slight variation in Pol% at brix values 13% and 14% when compared with 12% brix.

The pH values were higher than the standard pH (6.8 – 7.2). This slight increase in pH for all different brix values may lead to destruction of monosaccharides which cause color development due to the formation of melonoidins.

Table (2): Analysis of Clarified Juice at Different Brix Values.

Quality parameters	Brix 14	Brix 13	Brix 12
pH	8.38	8.31	8.36
Pol%	10.87	10.62	10.03
Purity%	78	82	84
Color	5737.9	6484.6	5950
Turbidity	7408	6484.4	5315

Determination of Phosphoric Acid in Mixed Juice

The use of phosphoric acid improves the clarification of refractory juice by its action in the precipitation of the colloids and coloring matter of the juice. The precipitate formed with lime is mainly tricalcium phosphate (Gillian and Margaret, 1998).

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Table (3) shows the obtained values of phosphoric acid in mixed juice (before and after treatment).

Values of phosphoric acid before treatment lie within the acceptable range. But phosphoric acid added to mixed juice was lower than the value stated by Karmarkar (1999).

Table (3): Phosphate Content of Mixed Juice before and After Addition.

Sample No	Phosphoric acid before addition (ppm)	Phosphoric acid after addition (ppm)
1	117	281
2	141	283
3	118	283

Turbidity

Clarified juice turbidity is used as an indicator of the efficiency of the clarification process (ICUMSA, 1994).

A clear juice is an indication of sharp and rapid precipitation with good coagulation of coarse suspended matter (Honig, 1970).

The turbidity analysis of clear juice samples is shown in Table (4). The turbidity results ranged between 3242 and 8567 and this is due to different levels of mud caused by mechanical harvest.

Color

The color of clear juice depends upon quality and optimum dosing of lime, pH control, temperature and its uniform flow, phosphate content of mixed juice, reaction time and flocculent dosing (Kampen, 1996).

Table (4) shows the color value of clear juice samples. The color values obtained were different ranging between 3910 – 13921 ICUMSA, and this variation was mainly due to high mud volume caused by mechanical harvest and to insufficient amount of phosphates of the juice as mentioned by Fort (1939), who stated that, the amount of color

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absorbed increases with the phosphate content of the juice to a certain limit then a gradual rise of color occurs due to the increase of reducing sugar (as a result of lowering pH) which react with amino acid in the browning reaction. Also the reducing sugars (RS) caramelize at high temperatures and assume a dark coloration.

Table (4): Turbidity and Color Values of Clear Juice.

Sample No	Turbidity	Color ICUMSA
1	8469	3910
2	7545	5678
3	8567	6032
4	3242	13921

Pol%, Purity and Reducing Sugar

Pol%

Polarization for all clarified juice samples was measured by automatic polarimeter calibrated in (ISS). The polarimeter reading pol% refers to sugar content and defined as apparent sucrose content (Honig, 1970).

Purity%:

True purity refers to percent sucrose in total soluble solids. The increase in purity is considered the most misleading of all figures determined in clarification studies (Honig, 1970).

A large part of the supposed purity increase is due to removal of suspended matter, and varies with different juices (Fort, 1939). An increase may also indicate a reduction of solids through the destruction of reducing sugars (Davies, 1942).

Figures(1). (2) Show Pol% and Purity% at different months during harvest.

The Pol% and Purity% were low at first harvest; this was due to increase of mud by mechanical harvest. The increase in mud volume may lead to increase in suspended matter which causes additional sucrose loss. Finally Pol% and Purity% were low due to the effect of temperature increase in the field.

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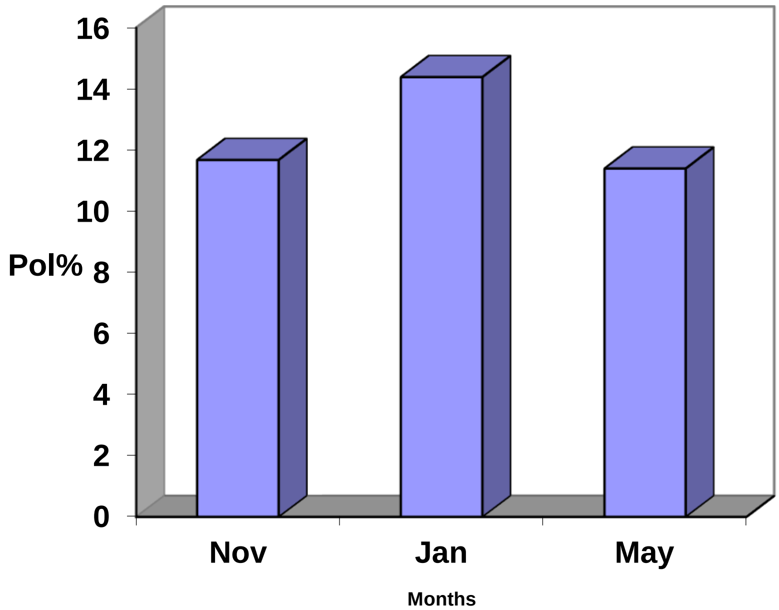

Fig (1): Pol% at Different Months

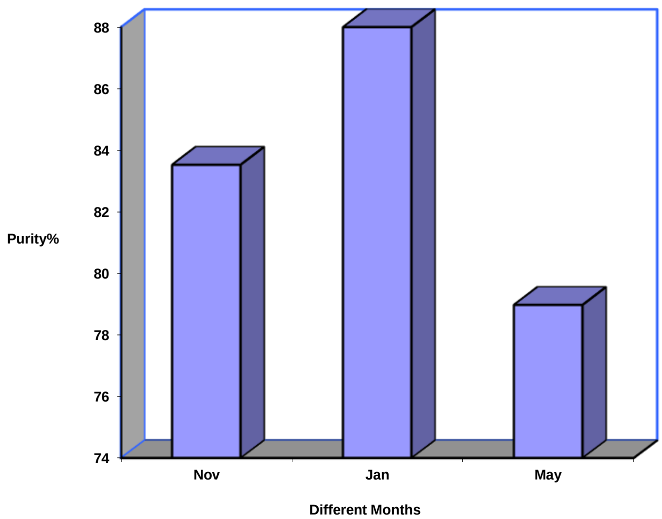

Fig: (2) Purity% changes against Months

Reducing Sugars

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Reducing sugar is always present in cane juice. Mostly consists of the hexoses, glucose and fructose. It is of great importance to keep inversion to a minimum in order to avoid loss of sucrose (Honig, 1970).

The analysis of reducing sugars, Pol% and Purity% of the obtained sample are shown in Table (5). The percentage of reducing sugars lie within the standard values (0.4 - 1.28) % according to Spencer and Mead (1963).

According to Meade and Chen (1985) the Pol% to a great extent is affected by sucrose stability during the clarification. From data obtained it is clear that the low Pol% and Purity% were found at the highest RS% value. That means Pol% and Purity% are in reverse relationship with RS%.

Temperature

The advantages of juice boiling reported by Karmarkar (1999) as follows:

1. The coagulation of precipitate formed is effective at high temperature.
2. The rate of reaction is faster at high temperature.

Table (6) shows incoming and outgoing temperature of juice from clarifier. The
This temperature drop was due to flash .C°temperature of juice dropped from 103 to 99
tank function, in which juice passes through it. Also juice transfer through the pipes lead to temperature drop in the clarifier.

pH Measurements:

According to Karmarkar (1999) the pH values must be in the range of 6.9 - 7.1 for clear juice. Baikow (1982) stated that, the raw cane juice is generally limed to pH 8.0 in order to obtain a clarified juice of pH 6.8 - 7.2. The pH values were summarized in table (7). It is clear that, there were different pH values between limed and clear juice due to variations in phosphate content and hence different concentration in hydrogen concentration. Also high pH drop between the limed and the clarified juice can cause considerable sugar losses. The obtained values for both clarified and limed juices lied within the standard range as confirmed by (Poel, 1998).

Table (5): RS%, Pol% and Purity% of Clear Juice.

RS%	Pol%	Purity
0.928	11.41	79

Table (6): Clear Juice Temperature.

Incoming temperature (̊c)	Out going temperature (̊C)
99	93

Table (7): pH Values of Limed and Clear Juice.

pH (limed juice)	pH (clear juice)
7.75	6.78

Retention Time

Table (8) shows clarifier retention time against crushing rate. Retention time obtained was lower than the standard value which is considered 2 - 3 hr (Baikow, 1982). This low retention time led to turbidity increase in clear juice and incomplete reaction time in which the calcium ions will be free and this will cause problems in the juice heaters and evaporators. These problems is known as scale formation in the evaporator tubes.

Also low retention time was due to increased supply of lime juice to the clarifier and this will not give enough time for the flocs to from in the clarifier, which may lead to increase in turbidity.

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Table (8): Crushing Rate vs. Clarifier Retention Time.

Months	Crushing rate (ton)	Retention time (hrs)
November	4530	1:50
January	4676	1:80
May	3986	1:43

Flocculants or Coagulants

In Elguneid sugar factory the separan used at 1.6 ppm, this is considered lower than the standard value which is in the range (2- 5) reported by Karmarcar (1999). Insufficient amount of separan lead to low settling of mud. Also the capacity of separan preparation tank was not enough for the separan to be dissolved completely. This low amount of separan added has its bad reflection on juice quality. So the clear juice obtained has a high turbidity and color, and this will add more load in the boiling house and in the centrifugation stage.

Influence of Cane Harvest on Mud Volume and Sugar Yield

Fig (3) and fig (4) shows the relationship between percentage of mechanical harvest and manual harvest against mud volume. When mechanical harvest increases high volume of mud was obtained. But when there was increase percentage of manual harvest, there was a decrease in mud volume.

In Fig (5) and fig (6) a relationship was found between percentage of sugar yield against percentage of mechanical and manual harvest. So, when there was an increase of mechanical harvest sugar yield% was decreased. But when a manual harvest was high, sugar recovery was more or higher.

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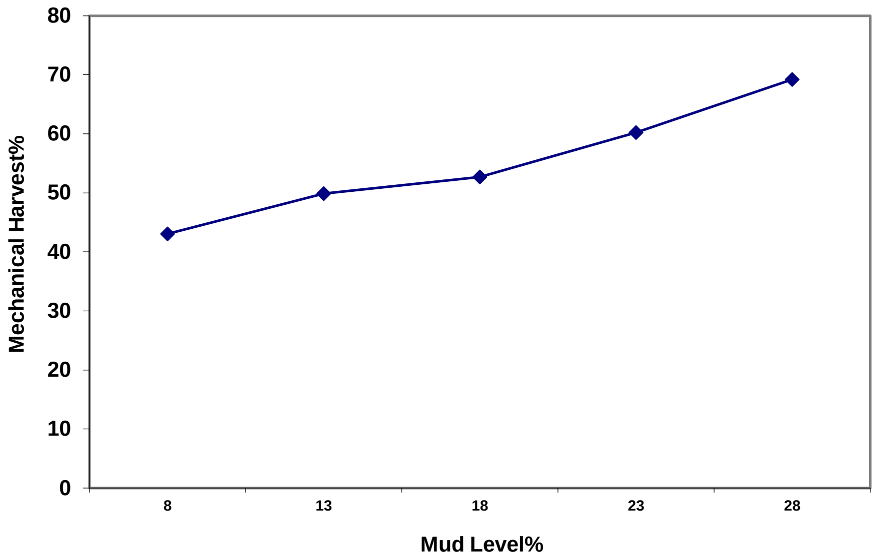
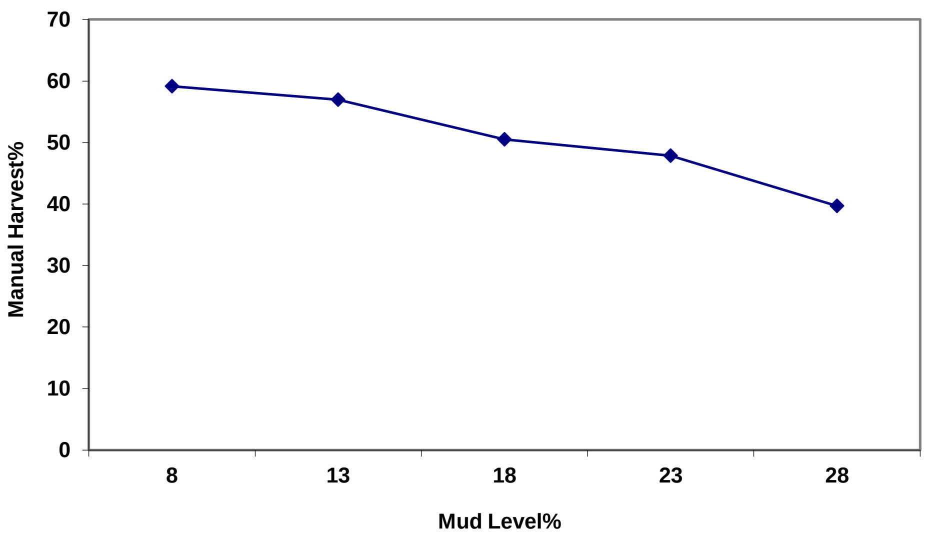


Fig (3)

Mechanical Harvest vs. Mud Level



Fig

(4) Manual Harvest vs. Mud level

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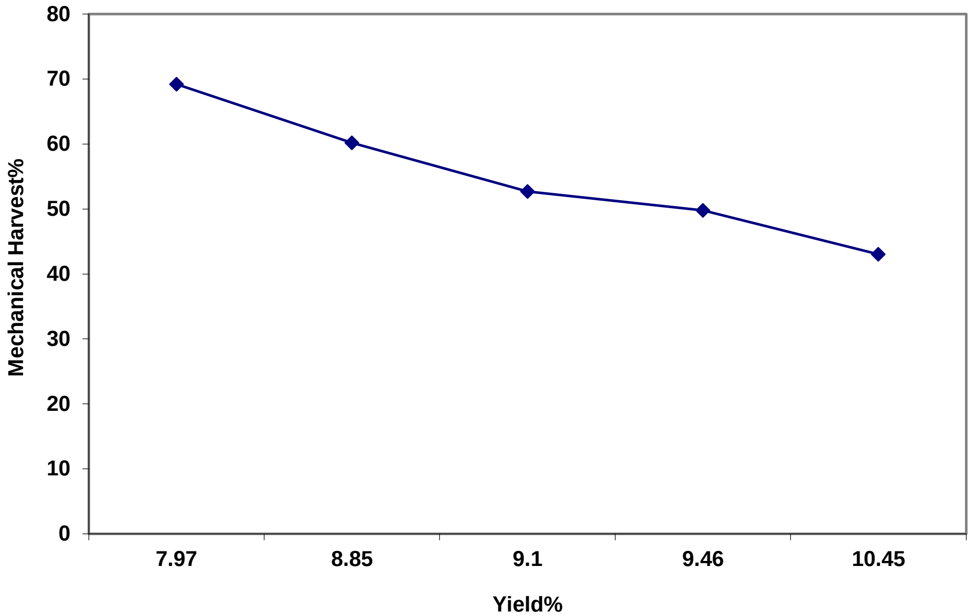

Fig (5) Sugar Yield vs. Mechanical Harvest

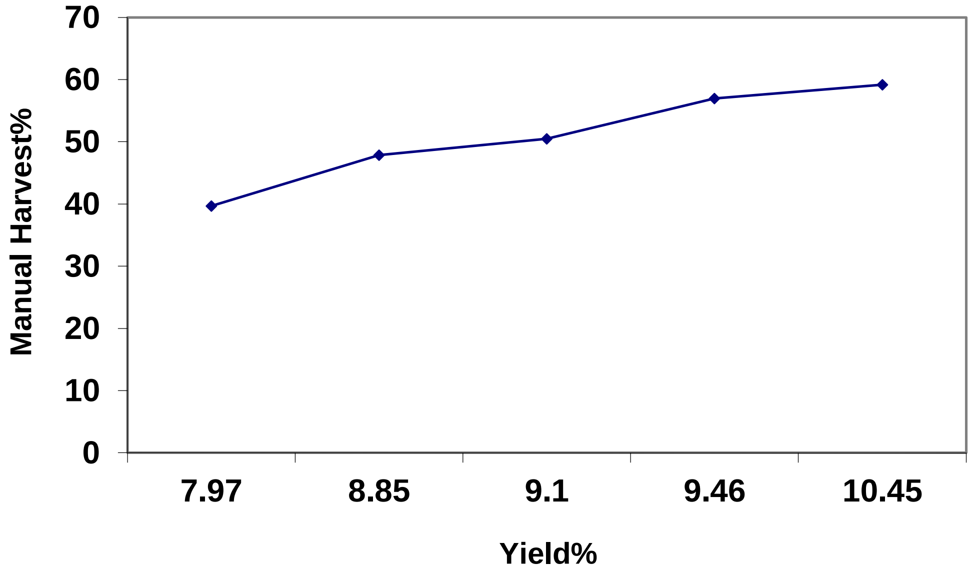

Fig (6) Sugar Yield vs. Manual Harvest

CONCLUSION

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The obtained results of this study pointed out the following:

The percentage of sucrose and Purity in clear juice was low, this was due to the high mud levels which come with sugar cane which is harvested mechanically.

Reducing sugar (R.S%), turbidity and color were increased due to high mud volume caused by mechanical harvest.

Amount of phosphoric acid and separan added in juice in Elguneid Sugar Factory were very low in comparison with the standard value.

The increased supply of limed juice to the clarifier has lead to lower retention time.

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